Porting the MUSIC Algorithm to the SuperDARN pyDARN Library for the Study of Traveling Ionospheric Disturbances

F. H. Tholley[1], N. A. Frissell[1] , W. Liles[2], J. B. H Baker[3], J. M. Ruohoniemi[3]

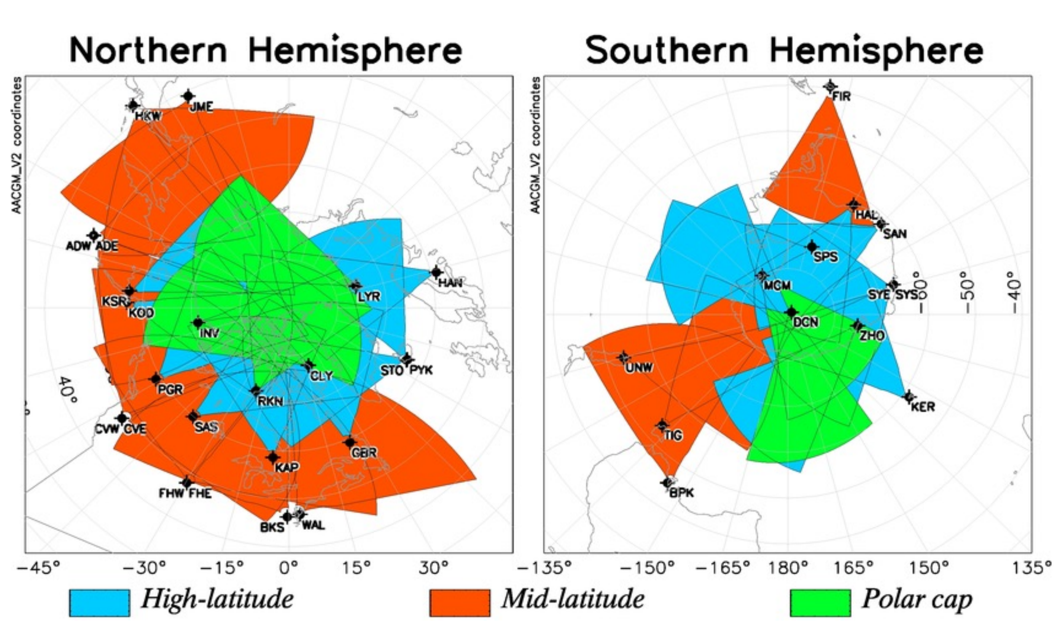
[1]University of Scranton, [2]HamSCI Community, [3]Virginia Tech

Introduction

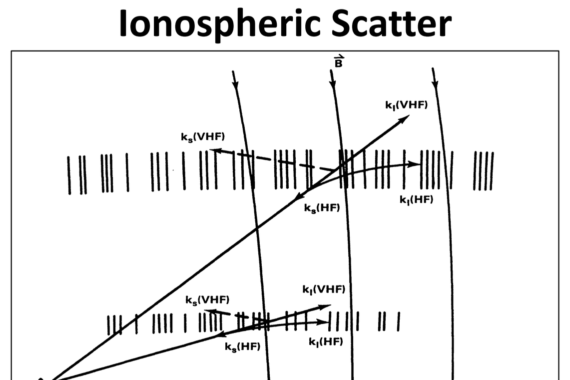
- Medium Scale Traveling Ionospheric Disturbances (MSTIDs) are quasi-periodic variations of the F-region ionosphere often associated with atmospheric gravity waves (AGWs) with periods of 15 to 60 minutes, horizontal velocities of and velocities between 100 and 250 m/s, and horizontal wavelengths of a few hundred kilometers (Ogawa et al., 1987).
- Statistical studies of MSTIDs using Super Dual Auroral Radar Network (SuperDARN) radars in the Northern Hemisphere have shown strong correlation with Polar Vortex activity (Frissell et al., 2016), while a study of MSTIDs using the Antarctic Falkland Islands SuperDARN radar showed populations of MSTIDs with signatures suggestive of both solar wind-magnetosphere coupling sources and lower neutral atmospheric winds sources (Grocott et al., 2013).
- Previous studies have used SuperDARN radars to observe MSTIDs and determine these characteristics using an implementation of the multiple signal classification (MUSIC) algorithm.
- **In this presentation, we try to show what analysis will be possible once we port the MUSIC implementation written in Python 2 for use with the deprecated SuperDARN Data and Visualization Toolkit python (DaViTpy) to Python 3 for use with the current pyDARN library.**

SuperDARN

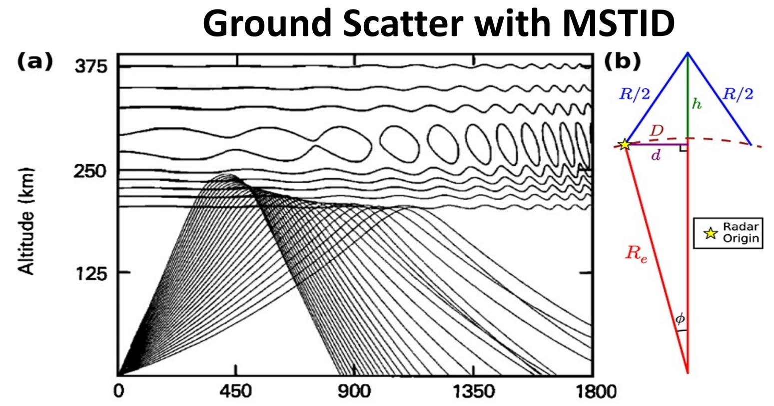
- SuperDARN is a network of high frequency (HF) radars located in both the Northern and Southern hemisphere for studying both mid- and high-latitude ionospheric dynamics (Nishitani et al., 2019; Greenwald et al., 1995).



- SuperDARN backscatter is classified as ionospheric (half-hop) or ground (single-hop) scatter.
- SuperDARN MSTIDs are typically seen in ground scatter due to the focusing and de-focusing of rays by the MSTID.
- Ionospheric scatter is presented using the slant range, while ground scatter is mapped to the ionospheric reflection point using the formula $D \approx R_e \sin^{-1}\left[\frac{\sqrt{R^2/(4-h^2)}}{R_e}\right]$ (Bristow et al., 1994).



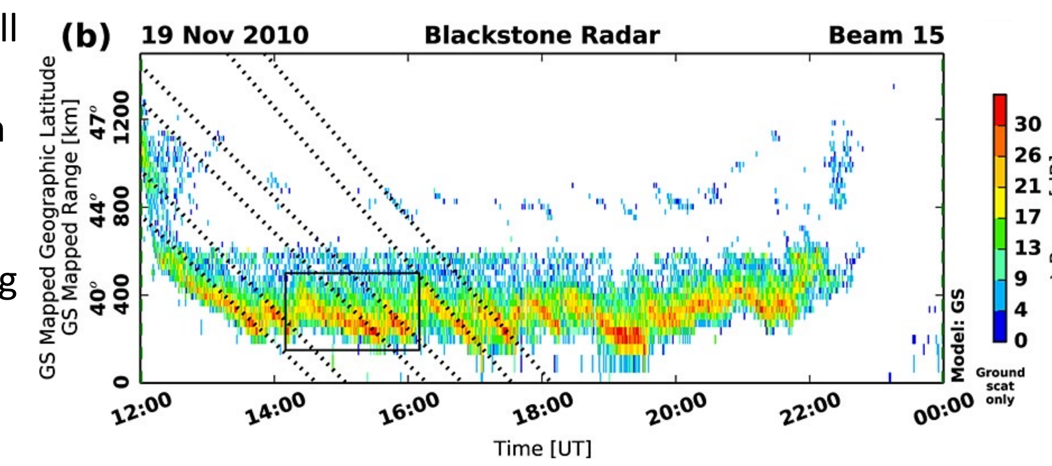
From Greenwald et al. (1995)



From Samson et al. (1990) and Frissell et al. (2014)

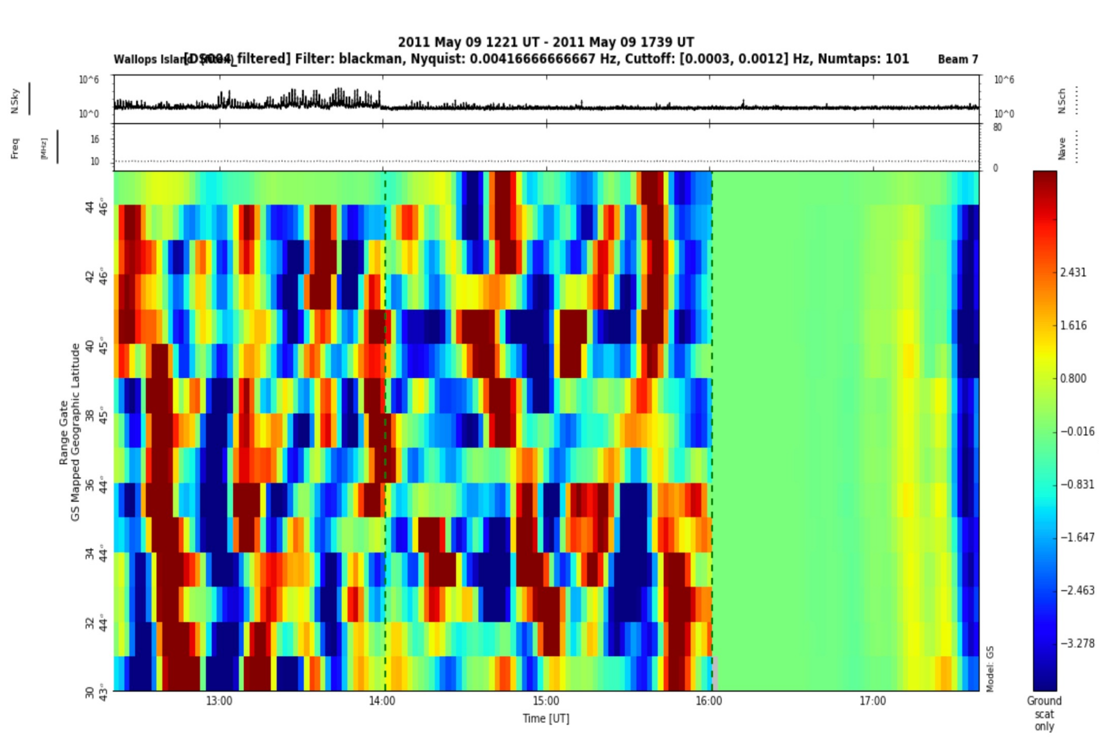
MSTID Signatures

- MSTID signatures can be observed in ground scatter power range-time-parameter (RTP) plots along single beams of the SuperDARN radars.
- In this figure from Frissell et al. (2014), MSTIDs with a period of ~32 min can be see moving towards the Blackstone, Virginia (BKS) radar along Beam 15 with a line-of-sight (LOS) velocity of ~88 m/s.

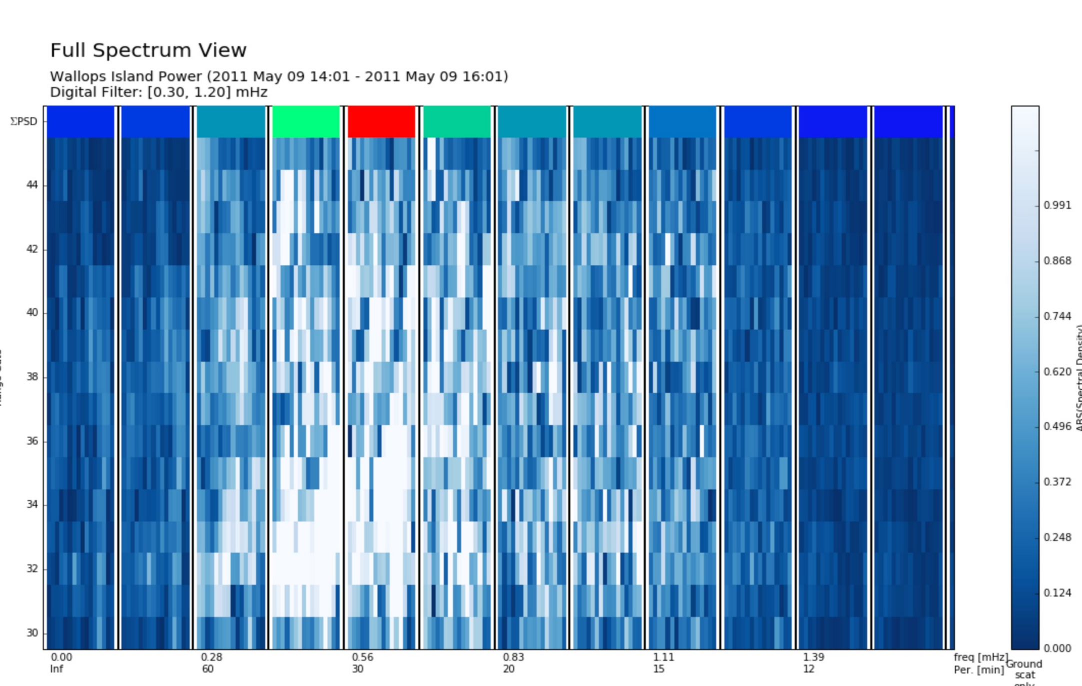


Multiple Signal Classification (MUSIC)

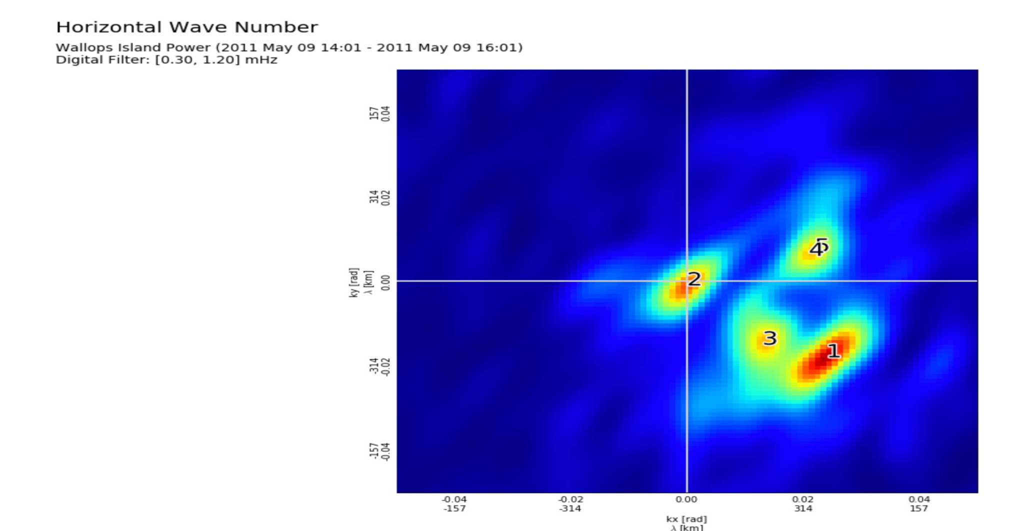
- To conduct a MUSIC analysis the data must first be interpolated to ensure that the data does not have any gaps in time or space.
- The Data for the diagram below is therefore interpolate in space and in time along the beams.
- We decide to use Wallops Island 09 May 2011 data to demonstrate the MUSIC algorithm.
- The data can then be filtered with a band pass filter using 0.5-1.2mHz(T=14-33 min) to isolate the dominant MSTIDs (Frissell et al. 2014).
- In this figure we plot RTP after filtering the data. The RTP plot starts from 12 UT to 18 UT after being filtered.
- We also set autoscale to True since the magnitudes will be much lower than the original data.



- The fast Fourier transform (FFT) and cross spectral matrix are calculated
- In this figure we plot the full spectrum view. Each FFT bin has 16 slices representing the data for each of the radar beams



- We then used the fast Fourier transform (FFT) and cross spectral matrix to calculate the horizontal wave number array described in Samson et al.[1990].
- An image processing watershed algorithm determines where in the array the largest local maximum occurs.
- In this figure the wave numbers are calculated and displayed.
- The plot data has been limited to just 14 - 16 UT.



Summary

- The MUSIC algorithm interpolates the data then filter it and uses FFT and spectral matrix to attain the horizontal wave numbers which are the dominant MSTIDs
- We are currently porting the MUSIC algorithm with pyDARN
- Our goal is to completely port the MUSIC algorithm to Python 3 with the pyDARN library.

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Francis.tholley@scranton.edu

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